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POWER TRANSMISSION BY FRICTION DRIVING

BY W. F. M. GOSS

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POWER TRANSMISSION BY FRICTION DRIVING

By W. F. M. GOSS, URBANA, ILL.
Member of the Society

A description of the application of friction wheels to ordinary forms of shaft driving, and an account of experiments made to determine the power capacity of such wheels when made of compressed straw fiber, was presented to the Society in December, 1896, under the caption of "Paper Friction Wheels." The facts herewith given are to be accepted as an extension of the earlier study.

A FRICTION DRIVE

2 A friction drive, as the term is here employed, consists of a fibrous or somewhat yielding driving wheel working in rolling contact with a metallic driven wheel. Such a drive may consist of a pair of plain cylindered wheels mounted upon parallel shafts, or of a pair of beveled wheels, or of any other arrangement which will serve in the transmission of motion by rolling contact. The use of such drives has steadily increased in recent years, with the result that the so called paper wheels have been improved in quality and a considerable number of new materials have been proposed for use in the construction of fibrous wheels.

THE WHEELS TESTED

3 Choosing materials which have been used for such purposes, driving wheels of each of the following materials have been tested:

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

Straw fiber,
Straw fiber with belt dressing,
Leather fiber,
Leather,
Leather-faced iron,
Sulphite fiber,
Tarred fiber.

4 The straw fiber wheels are worked out of blocks which are built up usually of square sheets of straw board laid one upon another with a suitable cementing material between them and compacted under heavy hydraulic pressure. In the finished wheel, the sheets appear as discs, the edges of which form the face of the wheel. The material works well under a tool, but is harder and heavier than most woods and takes a good superficial polish. The wheel tested was taken from stock.

5 The wheel of straw fiber with belt dressing was similar to that of straw fiber, except that the individual sheets of straw board from which it was made had been treated, prior to their being converted into a block, with a "belt dressing," the composition of which is unknown to the writer.

6 The leather fiber wheel was made up of cemented layers of board, as were those already described, but in this case, the board, instead of being of straw fiber, was composed of ground sole leather cuttings, imported flax and a small percentage of wood pulp. The material is very dense and heavy.

7 The leather wheel was composed of layers or disks of sole leather.

8 The leather-faced iron wheel consisted of an iron wheel having a leather strip cemented to its face. After less than 300 revolutions, the bond holding the leather face failed and the leather separated itself from the metal of the wheel. This wheel proved entirely incapable of transmitting power and no tests of it are recorded.

9 The wheel of sulphite fiber was made up of sheets of board composed of wood pulp. The sulphite board is said to have been made on a steam-drying continuous-process machine in the same way as is the straw board.

10 The tarred fiber wheel was made up of board composed principally of tarred rope stock, imported French flax and a small percentage of ground sole leather cuttings.

11 Each of the fibrous driving wheels was tested in combination with driven wheels of the following materials:

Iron,
Aluminum,
Type metal.

All wheels tested, both driving and driven, were 16 inches in diameter. The face of all driving wheels was $1\frac{3}{4}$ inch, while that of all driven wheels was $\frac{1}{2}$ inch.

12 The purpose of the experiments was to secure information which would permit rules to be formulated defining the power which may be transmitted by the various combinations of fibrous and metallic wheels already described. To accomplish this, it was necessary to determine for each combination of driving and driven wheel, the coefficient of friction under various conditions of operation; also the maximum pressures of contact which can be withstood by each of the fibrous wheels.

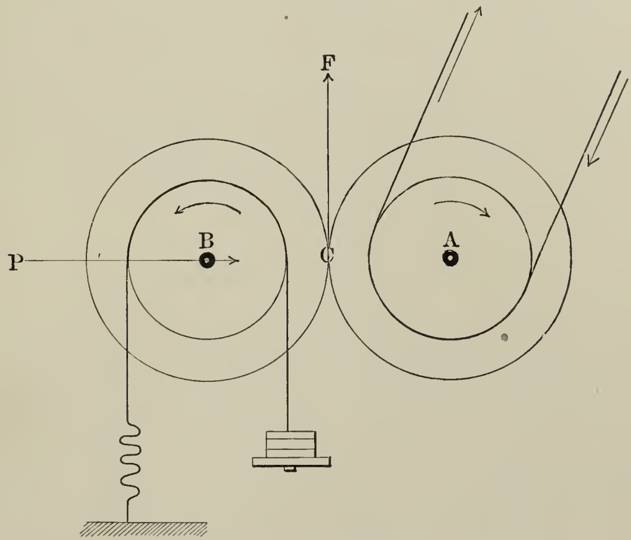

FIG. 1

13 The testing machine used is shown diagrammatically by Fig. 1. The principles involved will be made clear by assigning the functions of the actual machine to the several parts of this figure. The shaft *A* runs in fixed bearings, and carries the fibrous friction wheel. This wheel is the driver. Its shaft *A* carries, beside the friction wheel, two belt pulleys, one on either side, belts to which from any convenient source of power, serve to give motion to the driver. The shaft *B* carries the driven wheel which in every case was of metal. The bearings of this shaft are capable of receiving motion in a horizontal direction and by means of suitable mechanism connected therewith, the metal driven wheel may be made to press against the fibrous driver with any force desired. The pressure transmitted from *B* to *A*

is hereinafter referred to as the "pressure of contact," and is frequently represented by the symbol P. The tangential forces which are transmitted from the driver to the driven wheel are received, absorbed and measured by a friction brake upon the shaft B. In action, therefore, the driven wheel always works against a resistance, which resistance may be modified to any desired degree by varying the load upon the brake. The theory of the machine assumes that the energy absorbed by the brake equals that transmitted from the driver to the driven wheel at the contact point C. Accepting this assumption, the forces developed at the periphery of the brake wheel may readily be reduced to equivalent forces acting at the circumference of the driven wheel. This force, which is directly transmitted from the driver to the driven wheel, is hereinafter designated by the symbol F. It will be apparent from this description that the functions of the apparatus employed are such as will permit a study of the relationship existing between the contact pressure P and the resulting transmitted force F, which relation is most conveniently expressed as the coefficient of friction. It is,

$$f = \frac{F}{P}$$

It is obvious in comparing the work of two friction wheels, that the one which develops the highest coefficient of friction, other things being equal, can be depended upon to transmit the greatest amount of power.

14 The actual machine as used in the experiments is shown by Fig. 2. Its construction satisfies all conditions which have been defined except that shaft B, Fig. 1, does not run in bearings which are absolutely frictionless, as is required by a rigid adherence to the theoretical analysis already given. These bearings, however, are of the "standard roller bearing" type, and of ample size, and it is believed that the friction actually developed by them is so small compared with the energy transmitted between the wheels that it may be neglected.

15 The bearings of the fixed shaft A are secured to the frame of the machine. The bearings of the axle B are free to move horizontally in guides to which they are well fitted. These bearings are connected by links to the short arm of a bell-crank lever, the longer arm of which projects beyond the frame of the machine at the right hand end and carries the scale-pan and weights E. The effect of the weights is to bring the driven wheel in contact with the driver under a

predetermined pressure, the proportions of the bell-crank lever being such as to make this pressure in pounds equal,

$$P = 10\ W + 73$$

where W is the weight on the scale-pan E.

16 The fulcrum of the bell-crank lever is supported by a block G which may be adjusted horizontally by the hand wheel H at the rear of the machine, so that whatever may be the diameter of the driven wheel, the long arm of the bell-crank may be brought to a horizon-

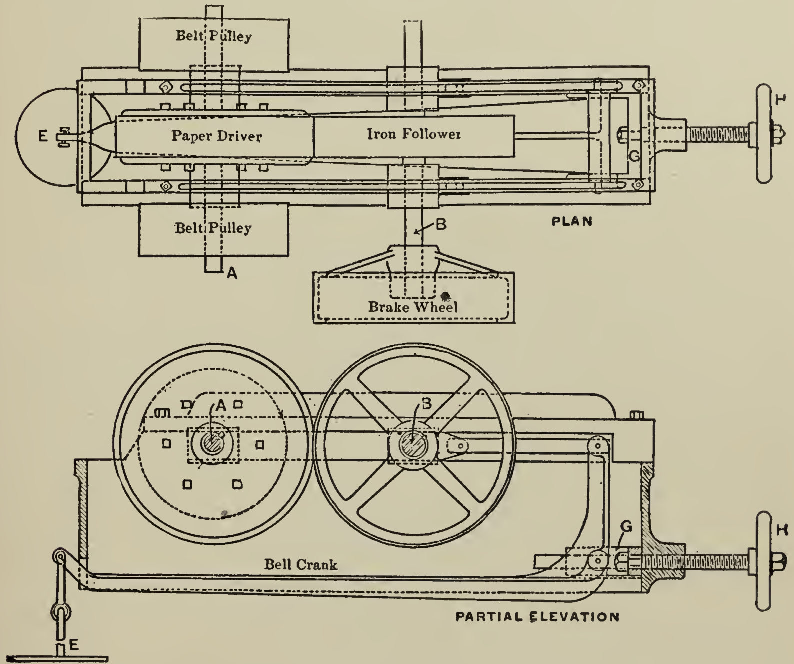

FIG. 2[a]

tal position. The constants employed in calculating the coefficient of friction from observed data are as follows:

Diameter of friction wheels (inches)	16
Effective diameter of brake (inches)	18.35
Ratio of diameter of friction wheel to that of brake wheel	1.145
Effective load on brake	F′
Coefficient of friction	$1.145 \frac{F'}{P}$

The slippage between the friction wheels was determined from readings taken from the counters connected to each one of the shafts.

[a] Reproduced from Vol. 18, Transactions.

THE TESTS

17 In proceeding with a test, load was applied to the scale-pan *E*, Fig. 2, to give the desired pressure of contact, after which the hand-wheel *H*, at the back of the machine was employed to bring the bell-crank to its normal position. This accomplished, with the driving wheel in motion, the driven wheel would roll with it under the desired pressure of contact. A light load was next placed upon the brake to introduce some resistance to the motion of the driven shaft, and conditions thus obtained were continued constant for a considerable period. Readings were taken simultaneously from the counters, and time noted. After a considerable interval, the counters were again read, time again noted, and the test assumed to have ended. From the readings of the counters, and from the known diameters of the wheels in contact, the per cent of slip attending the action of the friction wheels was calculated. Three facts were thus made of record, namely: *a* The pressure of contact; *b* the coefficient of friction developed, and *c* the per cent of slip resulting from the development of said coefficient of friction.

18 This record having been completed, the load upon the brake was increased, and observations repeated, giving for the same pressure of contact, a new coefficient of friction and a higher percentage of slip. This process was continued until the slippage became excessive and in consequence thereof, the rotation of the driver ceased. By this process a series of tests was developed disclosing the relation between slip and coefficient of friction for the pressure in question. Such a series having been completed, the load upon the weight holder *E* was changed, giving a new pressure of contact, and the whole process repeated. As the work proceeded, curves showing the relation of coefficient of friction and slip for pressures per inch width of face in contact of 150 pounds and 400 pounds, respectively, were secured. The curves shown by Fig. 3 and Fig. 4 for the straw fiber driving wheel, in contact with the iron driven wheel are typical in their general form of those obtained from all combinations of wheels, but the curves of no two combinations were alike in their numerical values.

19 Having completed this series of tests at constant pressure, a series was next run for which the coefficient of slip was maintained constant at 2 per cent and the pressure of contact varied from values which were low to those which are judged to be near the maximum for service conditions, with results which in all cases were similar in character with those given for the straw fiber and iron wheels, as set

forth by Fig. 5. The numerical values of the points for other combinations were not the same as those shown by Fig. 5, but in the case of most of the combinations the coefficient of friction at constant slip gradually diminishes as the pressure of contact is increased. With this understanding of the general character of the results, the precise facts in each case are presented in numerical form rather than graphically. See Appendix. Table 1–8.

20 As the series of tests involving each combination of wheels proceeded, the increase in pressure of contact was discontinued when the markings made upon the driving wheel by the metallic follower became so distinct as to suggest that a safe limit had been reached,

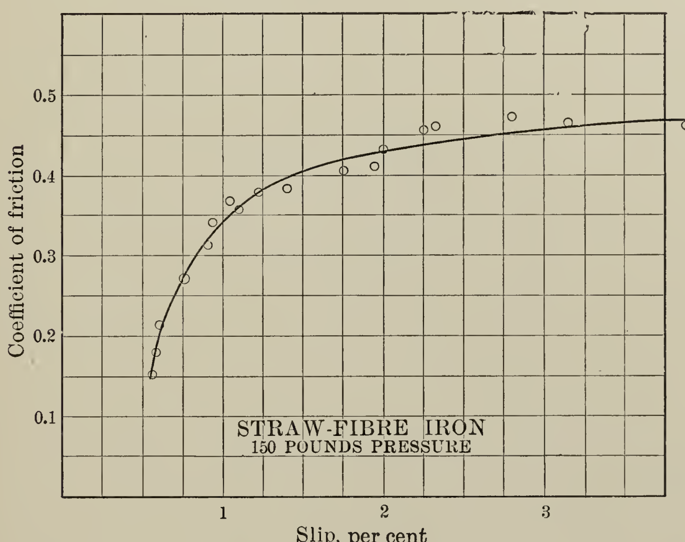

FIG. 3

but when all other data had been secured, tests were run for the purpose of determining the ultimate resistance of the fibrous wheel to crushing. The details of these will be described later.

Coefficient of Friction Developed by the Several Combinations of Wheels

STRAW FIBER AND IRON

21 The results of experiments involving a straw fiber driver, and an iron driven wheel are presented in the Appendix as Tests 1 to 36, Table 1. They are shown graphically in Fig. 3, 4 and 5. Fig. 4 and 5 illustrate the relation between slip and coefficient of friction when

the two wheels are working together under pressures per inch width of 150 and 400 pounds, respectively.

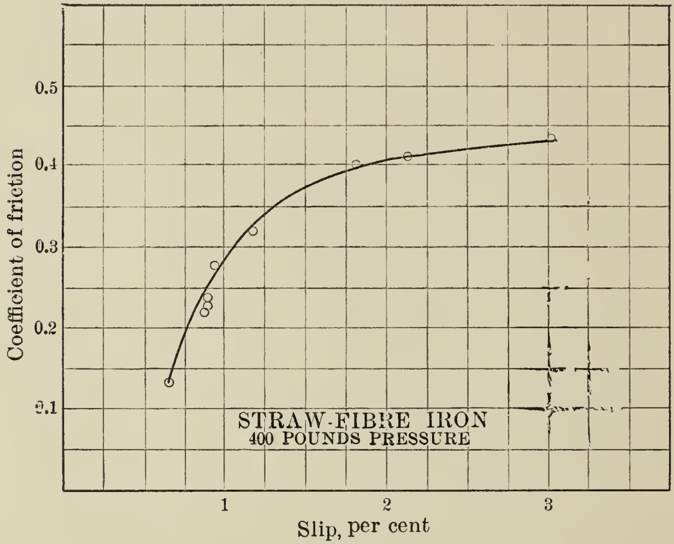

FIG. 4

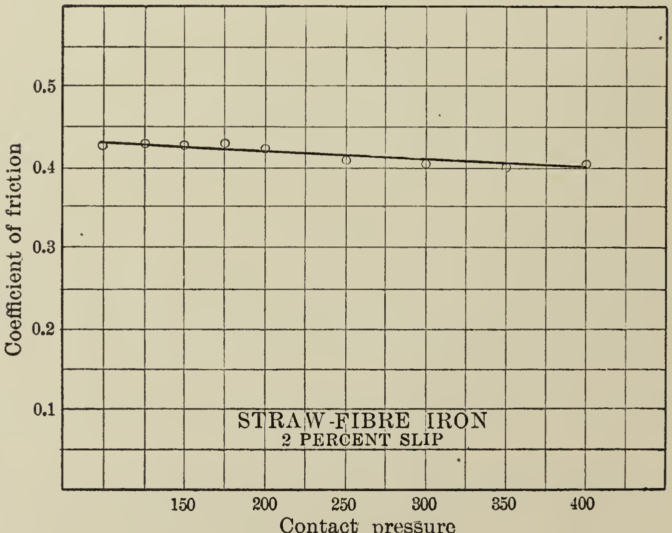

FIG. 5

22 The figures show that although the values of the coefficient of friction for 400 pounds pressure are slightly lower than corresponding

ones for 150 pounds pressures, the curves are sufficiently similar to establish the fact that the law governing change in coefficient of friction with slip is independent of the pressure of contact. When the slippage is 2 per cent, the coefficient of friction is 0.425 for a contact pressure of 150 pounds, and 0.410 for a contact pressure of 400 pounds. That the coefficients of friction for all pressures between the limits of 150 pounds and 400 pounds are practically constant is well shown by the diagram Fig. 5. The pressure of 400 pounds is the maximum at which tests of this combination of wheels were run, though straw fiber was successfully worked up to a pressure of 750 pounds.

STRAW FIBER AND ALUMINUM

23 The results of experiments involving a straw fiber driver and an aluminum driven wheel are given in the Appendix as Tests 37 to 60, Table 1. By curves plotted from values given, it can be shown that when the working pressure is 150 pounds per inch width and the slippage is 2 per cent, the coefficient of friction is 0.455; also, that for all pressures ranging from 100 to 400 pounds, the coefficient of friction is practically constant when the rate of slip is constant. The maximum pressure at which tests involving this combination of wheels were run was 400 pounds per inch width.

STRAW FIBER AND TYPE METAL

24 The results of experiments involving a straw fiber driver and a type metal driven wheel are presented in the Appendix as Tests 61 to 87, Table 1. By curves plotted from values given, it can be shown that when the two wheels are operated under a pressure of contact of 150 pounds per inch width and when the slip is 2 per cent, the coefficient of friction is 0.310; also, that for all pressures of contact ranging from 100 to 400 pounds, the coefficient of friction is practically constant when the slip is constant.

STRAW FIBER WITH BELT DRESSING AND IRON

25 The results of the experiments involving a straw fiber driver treated with belt dressing, and an iron driven wheel are presented in the Appendix as Tests 88 to 103, Table 2. Curves plotted from values given show that when the two wheels are worked together under a pressure of 150 pounds per inch width and when the slip is 2 per cent, the coefficient of friction is 0.12; also, that for all pressures up to 400 pounds per inch width, the coefficient of friction

remains constant. The greatest pressure at which tests of this combination of wheels were run was 500 pounds per inch width.

LEATHER FIBER AND IRON

26 The results of tests involving a leather fiber driver and an iron driven wheel are presented in the Appendix as Tests 104 to 127, Table 3. Curves plotted from these results show that when the two wheels are worked together under pressures of 150 pounds per inch in width and when the slip is 2 per cent, the coefficient of friction is 0.515. When the contact pressure is 300 pounds per inch width, the coefficient of friction is 0.510. The greatest pressure at which tests of this combination of wheels were run was 350 pounds per inch width, although leather fiber was successfully worked up to a pressure of 1200 pounds per inch width.

LEATHER FIBER AND ALUMINUM

27 The results of experiments involving a leather fiber driver and an aluminum driven wheel are presented in the Appendix as Tests 128 to 134, Table 3. Curves plotted from these results show that under a contact pressure of 150 pounds per inch width and a slip of 2 per cent, the coefficient of friction is 0.495. This value remains practically constant under all pressures. The maximum pressure used in tests of this combination of wheels was 400 pounds.

LEATHER FIBER AND TYPE METAL

28. The results of experiments involving a leather fiber driver and a type metal driven wheel are presented in the Appendix as Tests 135 to 146, Table 3. Curves plotted from these results show that when the wheels are operated under a contact pressure of 150 pounds per inch width and when the slip is 2 per cent, the coefficient of friction is 0.305; also, that with the slip constant, the coefficient of friction remains constant for all pressures up to 400 pounds per inch width.

TARRED FIBER AND IRON

29 The results of the experiments involving a tarred fiber driver and an iron driven wheel are presented in the Appendix as Tests 147 to 166 and 267 to 269, Table 4. Curves plotted from these results show that the change in the value of the coefficient of friction with change of slip is practically independent of the pressure of contact.

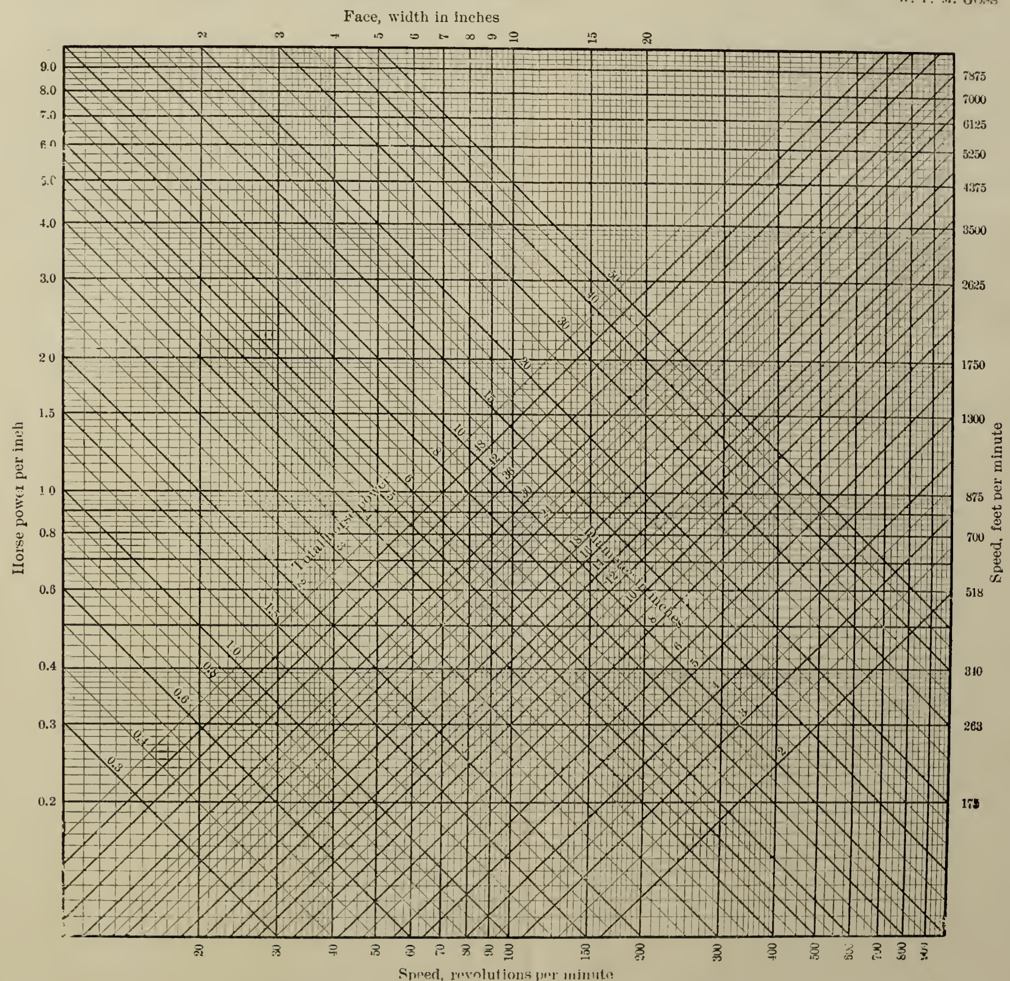

FIG. 6 THE FORMULA USED IN CALCULATING THIS CHART IS

h. p. = 0.0003 dWN, where d = diameter

W = width

N = revolutions

When the slip is 2 per cent, the coefficient of friction is 0.220 for a pressure of contact of 150 pounds, and 0.250 for a pressure of contact of 400 pounds per inch width.

30 The fact that the data for this combination appear in two series results from the use of a duplicate tarred fiber driver. Tests of this combination were made also under different speeds when the wheels were working together under a pressure of contact of 250 pounds per inch width and when the slip was 2 per cent, with the result that the coefficient of friction was found to remain nearly constant for speeds of 450 and 3350 feet per minute, respectively. The greatest pressure at which tests of this combination of wheels were run was 400 pounds per inch width, although tarred fiber was successfully worked up to a pressure of 1200 pounds per inch width.

TARRED FIBER AND ALUMINUM

31 The results of experiments involving a tarred fiber driver and an aluminum driven wheel are presented in the Appendix as Tests 167 to 186, Table 4. Curves plotted from these results show that when the slip was 2 per cent and the pressure of contact 150 pounds per inch width, the coefficient of friction is 0.305; also, that for a pressure of 400 pounds per inch width, the coefficient of friction is 0.295. The greatest pressure at which tests of this combination were run was 400 pounds per inch width.

TARRED FIBER AND TYPE METAL

32 The results of experiments involving a tarred fiber driver and a type metal driven wheel are presented in the Appendix as Tests 187 to 202, Table 4. Curves plotted from these results show that when the slip is 2 per cent, the coefficient of friction developed under 150 pounds pressure per inch width is 0.275; and under 400 pounds pressure per inch width, the coefficient of friction is 0.270. The maximum pressure at which tests of this combination of wheels were run was 400 pounds per inch width.

LEATHER AND IRON

33 The results of experiments involving a leather driver and an iron driven wheel are presented in the Appendix as Tests 203 to 220, Table 5. Curves plotted from these results show that when the slip is 2 per cent, the coefficient of friction under a pressure of contact of 150 pounds per inch in width, is 0.225, and under a pressure of 400 pounds, 0.215. The maximum pressure at which tests of this com-

bination of wheels were run was 400 pounds per inch width, although the leather driver was successfully operated up to a pressure of 750 pounds per inch width.

LEATHER AND ALUMINUM

34 The results of experiments involving a leather driver and an aluminum driven wheel are presented in the Appendix as Tests 221 to 234, Table 5. Curves plotted from these results show that when the pressure is 150 pounds per inch in width, and the slip is 2 per cent, the coefficient of friction is 0.260, and when the pressure is 300 pounds per inch in width, the coefficient of friction is 0.295. The maximum pressure at which tests of this combination of wheels were made was 350 pounds per inch width.

LEATHER AND TYPE METAL

35 The results of the experiments involving a leather driver and a type metal driven wheel are presented in the Appendix as Tests 235 to 239, Table 5. Curves plotted from these results show that when the slip is 2 per cent and the contact pressure 150 pounds per inch width, the coefficient of friction developed is 0.410. The greatest pressure at which tests of this combination of wheels were run was 350 pounds per inch width.

SULPHITE FIBER AND IRON

36 The results of the experiments involving a sulphite fiber driver and an iron driven wheel are presented in the Appendix as Tests 240 to 245, Table 5. Curves plotted from these results show that when the slip is 2 per cent and the pressure 150 pounds per inch width, the coefficient of friction is 0.550. The maximum pressure at which tests of this combination of wheels were run was 350 pounds per inch width, although the sulphite fiber wheel was successfully operated up to a pressure of 700 pounds per inch width.

SULPHITE FIBER AND ALUMINUM

37 The results of the experiments involving a sulphite fiber driver and an aluminum wheel are presented in the Appendix as Tests 245 to 249, Table 5. Curves plotted from these values show that when the slip is 2 per cent and the pressure 150 pounds per inch width, the coefficient of friction developed is 0.410. The greatest pressure used in tests of this combination of wheels was 350 pounds per inch width.

SULPHITE FIBER AND TYPE METAL

38 The results of the experiments involving a sulphite fiber driver and a type metal driven wheel are presented in the Appendix as Tests 250 to 254, Table 6. Curves plotted from these results show that when the slip is 2 per cent and the contact pressure 150 pounds per inch width, the coefficient of friction is 0.515. The maximum pressure used in tests of this combination of wheels was 350 pounds per inch width.

RESISTANCE TO CRUSHING

39 Upon the completion of tests designed to disclose the frictional qualities of the several combinations, each fibrous wheel was subjected to test for the purpose of determining the maximum pressure per inch width of the face which could be sustained by it. This was accomplished by placing the wheel to be tested in the machine, under a pressure of contact of 200 pounds per inch width. The load on the brake was then adjusted to give a 2 per cent slip and this brake load was maintained without change throughout the remainder of the tests. Thus adjusted, the machine was operated until the driver had completed 15 000 revolutions. This accomplished, and for the purpose of determining the reduction, if any, in the diameter of the fibrous wheel, the brake load was removed and the operation of the machine continued without load for a period of 6000 revolutions, the readings of the counters being taken at the beginning and end of the period. Under conditions of no load, the actual slip was assumed to be zero and the apparent slip observed was used for determining the reduction in diameter of the fibrous wheel which had been brought about by the previous running under pressure. This accomplished, the pressure of contact was increased, usually by 100-pound increments, and the whole operation repeated. This process was continued until failure of the fibrous wheel resulted. It will be seen that the ultimate resistance to crushing, as found by the process described, is that pressure which could not be endured during 15 000 revolutions.

40 A summary of results is as follows:

STRAW FIBER

Load = 200 .... Decrease in diameter = 0.000
Load = 650 .... Decrease in diameter = 0.053
Load = 750 .... Decrease in diameter = 0.125

Note—The wheel failed before running 15 000 revolutions under 750 pounds pressure.

LEATHER FIBER

Load = 200	Decrease in diameter = 0.000
Load = 300	Decrease in diameter = 0.005
Load = 400	Decrease in diameter = 0.013
Load = 500	Decrease in diameter = 0.021
Load = 600	Decrease in diameter = 0.027
Load = 700	Decrease in diameter = 0.040
Load = 800	Decrease in diameter = 0.051
Load = 900	Decrease in diameter = 0.068
Load = 1000	Decrease in diameter = 0.099
Load = 1100	Decrease in diameter = 0.125
Load = 1200	Decrease in diameter = 0.200

Note—The wheel failed before running 15 000 revolutions under 1200 pounds pressure.

TARRED FIBER

Load = 200	Decrease in diameter = 0.000
Load = 300	Decrease in diameter = 0.026
Load = 400	Decrease in diameter = 0.038
Load = 500	Decrease in diameter = 0.052
Load = 600	Decrease in diameter = 0.071
Load = 700	Decrease in diameter = 0.098
Load = 800	Decrease in diameter = 0.138
Load = 900	Decrease in diameter = 0.182
Load = 1000	Decrease in diameter = 0.250
Load = 1100	Decrease in diameter = 0.295
Load = 1200	Decrease in diameter =

Note—The wheel failed before running 15 000 revolutions under 1200 pounds pressure.

LEATHER

Load = 350	Decrease in diameter = 0.047
Load = 450	Decrease in diameter = 0.090
Load = 550	Decrease in diameter = 0.150
Load = 650	Decrease in diameter = 0.240
Load = 750	Decrease in diameter =

Note—The wheel failed before running 15 000 revolutions under 750 pounds pressure.

SULPHITE FIBER

Load = 200	Decrease in diameter = 0.010
Load = 300	Decrease in diameter = 0.032
Load = 400	Decrease in diameter = 0.056
Load = 500	Decrease in diameter = 0.088
Load = 600	Decrease in diameter = 0.146
Load = 700	Decrease in diameter = 0.258

Note—The wheel failed before running 15 000 revolutions under 700 pounds pressure.

A CONCLUSION AS TO METAL WHEELS

41 An examination of Table 9, which presents a comparison of values representing the coefficient of friction of the several combinations of wheels tested, reveals the fact that the relative value of the

metal driven wheels is not the same when operated in combination with different fibrous driving wheels. It appears that those driving wheels which are the more dense, work more efficiently with the iron follower than with either the aluminum or type metal followers but in the case of the softer and less dense driving wheels, and especially in the case of those in which an oily substance is incorporated, driven wheels of aluminum and type metal are superior to those of iron. Finely powdered metal which is given off from the surface of the softer metal wheels seems to account for this effect and the character of the driving wheels is perhaps the only factor necessary to determine whether its presence will be beneficial or detrimental. Finally, with reference to the use of soft metal driven wheels, it should be noted that no combination of such wheels with a fibrous driver appears to have given high frictional results. Except when used under very light pressures, the wear of the type metal was too rapid to make a wheel of this material serviceable in practice.

CONCLUSIONS AS TO FIBROUS WHEELS

42 The relative value of the different fibrous wheels when employed as drivers in a friction drive may be judged by comparing their frictional qualities as set forth in Table 9 and their strength as set forth in paragraph 41. The results show at once that the addition of belt dressing to the composition of a straw fiber wheel is fatal to its frictional qualities. The highest frictional qualities are possessed by the sulphite fiber wheel which, on the other hand, is the weakest of all wheels tested. The leather fiber and tarred fiber are exceptionally strong and the former possesses frictional qualities of a superior order. The plain straw fiber which in a commercial sense is the most available of all materials dealt with, when worked upon an iron follower, possesses frictional qualities which are far superior to leather, and strength which is second only to the leather fiber and the tarred fiber.

The Power Capacity of Friction Gears

CONCERNING THE APPLICATION OF RESULTS

43 A review of the data discloses the fact that several of the friction wheels tested developed a coefficient of friction which in some cases exceeded 0.5. That is, such wheels rolling in contact have transmitted from driver to driven wheels a tangential force equal to 50 per cent of the force maintaining their contact. These wheels, also, were successfully worked under pressures of contact approaching

500 pounds per inch in width. Employing these facts as a basis from which to calculate power, it can readily be shown that a friction wheel a foot in diameter, if run at 1000 revolutions per minute, can be made to deliver in excess of 25 horse power for each inch in width. It is certainly true that any of the wheels tested may be employed to transmit for a limited time an amount of power which, when gaged by ordinary measures, seems to be enormously high, but obviously, performance under limiting conditions should not be made the basis from which to determine the commercial capacity of such devices. In view of this fact, it is important that there be drawn from the data such general conclusions with reference to pressures of contact, and frictional qualities as will constitute a safe guide to practice.

WORKING PRESSURE OF CONTACT

44 The results of these experiments do not furnish an absolute measure of the most satisfactory pressure of contact for service conditions. Other things being equal, the power transmitted will be proportional to this pressure and hence it is desirable that the value be made as high as practicable. On the other hand, it has been noted as one of the observations of the test that as higher pressures are used, there appears to be a gradual yielding of the structure of the fibrous wheels, and it is reasonable to conclude that the life of a given wheel will in a large measure depend upon the pressure under which it is required to work. After a careful study of the facts involved, it has been determined to base an estimate of the power which may be transmitted upon a pressure of contact which is 20 per cent of the ultimate resistance of the material as established by the crushing tests already described. This basis gives the following results:

SAFE WORKING PRESSURES OF CONTACT

Straw fiber	pressure = 150
Leather fiber	pressure = 240
Tarred fiber	pressure = 240
Sulphite fiber	pressure = 140
Leather	pressure = 150

COEFFICIENT OF FRICTION

45 The coefficient of friction for all wheels tested approaches its maximum value when the slip between driver and driven wheel amounts to 2 per cent and, within narrow limits, its value is practically independent of the pressure of contact. A summary of maximum results is shown by Table 9. In view of these facts, it is pro-

posed to base a measure of the power which may be transmitted by such friction wheels as those tested upon the frictional qualities developed at a pressure of 150 pounds per inch of width, when operating under a load causing 2 per cent slip. For safe operation, however, deductions must be made from the observed values. Thus, the results of the experiments disclose the power transmitted from wheel to wheel, while in the ordinary application of friction drives some power will be absorbed by the journals of the driven axle so that the amount of power which can be taken from the driven shaft will be somewhat less than that transmitted to the wheel on said shaft. Again, under the conditions of the laboratory, every precaution was taken to keep the surfaces in contact free of all foreign matter. It was, for example, observed that the accumulation of laboratory dust upon the surfaces of the wheels had a temporary effect upon the frictional qualities of the wheels, and friction wheels in service are not likely to be as carefully protected as were those in the laboratory. In view of these facts, it has been thought proper to use as the basis from which to determine the amount of power which may be transmitted by such wheels as those tested, a coefficient of friction which shall be 60 per cent of that developed under the conditions of the laboratory. This basis gives the following results:

COEFFICIENT OF FRICTION—WORKING VALUES

Straw fiber and iron	coefficient of friction = 0.255
Straw fiber and aluminum	coefficient of friction = 0.273
Straw fiber and type metal	coefficient of friction = 0.186
Leather fiber and iron	coefficient of friction = 0.309
Leather fiber and aluminum	coefficient of friction = 0.297
Leather fiber and type metal	coefficient of friction = 0.183
Tarred fiber and iron	coefficient of friction = 0.150
Tarred fiber and aluminum	coefficient of friction = 0.183
Tarred fiber and type metal	coefficient of friction = 0.165
Sulphite fiber and iron	coefficient of friction = 0.330
Sulphite fiber and aluminum	coefficient of friction = 0.318
Sulphite fiber and type metal	coefficient of friction = 0.309
Leather and iron	coefficient of friction = 0.135
Leather and aluminum	coefficient of friction = 0.216
Leather and type metal	coefficient of friction = 0.246

HORSE POWER

46 Having now determined a safe working pressure of contact and a representative value for the coefficient of friction, it is possible to formulate equations expressing the horse power which may be transmitted by each combination of wheels tested. Thus, calling d the

diameter of the friction wheel in inches, W the width of its face in inches and N the number of revolutions per minute, the equations become, for combinations of,

Straw fiber and iron	h.p. = $0.00030\ dWN$
Straw fiber and aluminum	h.p. = $0.00033\ dWN$
Straw fiber and type metal	h.p. = $0.00022\ dWN$
Leather fiber and iron	h.p. = $0.00059\ dWN$
Leather fiber and aluminum	h.p. = $0.00057\ dWN$
Leather fiber and type metal	h.p. = $0.00035\ dWN$
Tarred fiber and iron	h.p. = $0.00029\ dWN$
Tarred fiber and aluminum	h.p. = $0.00035\ dWN$
Tarred fiber and type metal	h.p. = $0.00031\ dWN$
Sulphite fiber and iron	h.p. = $0.00037\ dWN$
Sulphite fiber and aluminum	h.p. = $0.00035\ dWN$
Sulphite fiber and type metal	h.p. = $0.00034\ dWN$
Leather and iron	h.p. = $0.00016\ dWN$
Leather and aluminum	h.p. = $0.00026\ dWN$
Leather and type metal	h.p. = $0.00029\ dWN$

47 By use of the first of these formulae, values have been calculated showing the horse power which may be transmitted by a straw fiber driver of one inch width of face in contact with an iron driven wheel. These values are presented as Table 10 accompanying. They include diameters which range from 3 to 53 inches and speeds of revolutions ranging from 100 to 2000. While the values of this table apply only to a combination of straw fiber and iron, it is possible by the use of a mutiplier to secure from them values which correspond to other combinations. Such a list of mutipliers is given below:

MULTIPLIERS

Straw fiber and aluminum	= 1.10
Straw fiber and type metal	= 0.73
Leather fiber and iron	= 1.97
Leather fiber and aluminum	= 1.90
Leather fiber and type metal	= 1.17
Tarred fiber and iron	= 0.97
Tarred fiber and aluminum	= 1.17
Tarred fiber and type metal	= 1.03
Sulphite fiber and iron	= 1.23
Sulphite fiber and aluminum	= 1.17
Sulphite fiber and type metal	= 1.13
Leather and iron	= 0.53
Leather and aluminum	= 0.87
Leather and type metal	= 0.97

48 For example, to determine the amount of power which can be transmitted by a given friction wheel of sulphite fiber working upon an iron driven wheel, values which are given in Table 10 should be

TABLE 10

HORSE POWER TRANSMITTED PER INCH OF WIDTH BY STRAW FIBER FRICTION WHEELS

Revolutions Per Minute

Diameter of Wheel	100	120	140	160	180	200	220	240	260	280	300
3	0.09	0.11	0.13	0.14	0.16	0.18	0.20	0.22	0.23	0.25	0.27
4	0.12	0.14	0.17	0.19	0.22	0.24	0.26	0.29	0.31	0.24	0.36
5	0.15	0.18	0.21	0.24	0.27	0.30	0.33	0.36	0.39	0.42	0.45
6	0.18	0.22	0.25	0.29	0.32	0.36	0.40	0.43	0.47	0.50	0.54
7	0.21	0.25	0.29	0.34	0.38	0.42	0.46	0.50	0.55	0.59	0.63
8	0.24	0.29	0.34	0.38	0.43	0.48	0.53	0.58	0.62	0.67	0.72
9	0.27	0.32	0.38	0.43	0.49	0.54	0.59	0.65	0.70	0.76	0.81
10	0.30	0.36	0.42	0.48	0.54	0.60	0.66	0.72	0.78	0.84	0.90
11	0.33	0.40	0.46	0.53	0.59	0.66	0.73	0.79	0.86	0.92	0.99
12	0.36	0.43	0.50	0.58	0.65	0.72	0.79	0.86	0.94	1.01	1.08
13	0.39	0.47	0.55	0.62	0.70	0.78	0.86	0.94	1.01	1.09	1.17
14	0.42	0.50	0.59	0.67	0.76	0.84	0.92	1.01	1.09	1.18	1.26
15	0.45	0.54	0.63	0.72	0.81	0.90	0.99	1.08	1.17	1.26	1.35
16	0.48	0.58	0.67	0.77	0.86	0.96	1.06	1.15	1.25	1.34	1.44
17	0.51	0.61	0.61	0.82	0.92	1.02	1.12	1.22	1.33	1.43	1.53
18	0.54	0.65	0.66	0.86	0.97	1.08	1.19	1.30	1.40	1.51	1.62
19	0.57	0.68	0.70	0.91	1.03	1.14	1.25	1.37	1.48	1.60	1.71
20	0.60	0.72	0.74	0.96	1.08	1.20	1.32	1.44	1.56	1.68	1.80
21	0.63	0.76	0.78	1.01	1.13	1.26	1.39	1.51	1.64	1.76	1.89
22	0.66	0.79	0.82	1.06	1.19	1.32	1.45	1.58	1.72	1.85	1.98
23	0.69	0.83	0.87	1.10	1.24	1.38	1.52	1.66	1.79	1.93	2.07
24	0.72	0.86	0.91	1.13	1.30	1.44	1.58	1.73	1.87	2.02	2.16
25	0.75	0.90	0.95	1.20	1.35	1.50	1.65	1.80	1.95	2.10	2.25
26	0.78	0.94	0.99	1.25	1.40	1.56	1.72	1.87	2.03	2.18	2.34
27	0.81	0.97	1.03	1.30	1.46	1.62	1.78	1.95	2.11	2.27	2.43
28	0.84	1.01	1.08	1.34	1.51	1.68	1.85	2.02	2.18	2.35	2.52
29	0.87	1.04	1.12	1.39	1.57	1.74	1.91	2.09	2.26	2.44	2.61
30	0.90	1.08	1.16	1.44	1.62	1.80	1.98	2.16	2.34	2.52	2.10
31	0.93	1.12	1.20	1.49	1.67	1.86	2.05	2.23	2.42	2.60	2.79
32	0.96	1.15	1.24	1.54	1.73	1.92	2.11	2.31	2.50	2.69	2.88
33	0.99	1.19	1.29	1.58	1.78	1.98	2.18	2.38	2.57	2.77	2.97
34	1.02	1.22	1.33	1.63	1.84	2.04	2.24	2.45	2.65	2.86	3.06
35	1.05	1.26	1.37	1.68	1.89	2.10	2.31	2.52	2.73	2.94	3.15
36	1.08	1.30	1.41	1.73	1.94	2.16	2.38	2.59	2.81	3.02	3.24
37	1.11	1.33	1.45	1.78	2.00	2.22	2.44	2.67	2.89	3.11	3.33
38	1.14	1.37	1.50	1.82	2.05	2.28	2.51	2.74	2.96	3.19	3.42
39	1.17	1.40	1.54	1.87	2.11	2.34	2.57	2.81	3.04	3.28	3.51
40	1.20	1.44	1.58	1.92	2.16	2.40	2.64	2.88	3.12	3.36	3.60
41	1.23	1.48	1.62	1.97	2.21	2.46	2.71	2.95	3.20	3.44	3.69
42	1.26	1.51	1.66	2.02	2.27	2.52	2.77	3.03	3.28	3.53	3.78
43	1.29	1.55	1.71	2.06	2.32	2.58	2.84	3.10	3.35	3.61	3.87
44	1.32	1.58	1.75	2.11	2.38	2.64	2.90	3.17	3.43	3.70	3.96
45	1.35	1.62	1.79	2.16	2.43	2.70	2.97	3.24	3.51	3.78	4.05
46	1.32	1.66	1.83	2.21	2.48	2.76	3.04	3.31	3.59	3.86	4.14
47	1.41	1.69	1.87	2.26	2.54	2.82	3.10	3.39	3.67	3.95	4.23
48	1.44	1.73	1.91	2.30	2.59	2.88	3.17	3.46	3.74	4.03	4.32
49	1.47	1.76	1.96	2.35	2.65	2.94	3.23	3.53	3.82	4.12	4.41
50	1.50	1.80	2.00	2.40	2.70	3.00	3.30	3.60	3.90	4.20	4.50

Diameter of Wheel	325	350	375	400	425	450	475	500	550	600
3	0.29	0.32	0.34	0.36	0.38	0.41	0.43	0.45	0.50	0.54
4	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.60	0.66	0.72
5	0.49	0.53	0.56	0.60	0.64	0.68	0.71	0.75	0.83	0.90
6	0.59	0.63	0.68	0.72	0.77	0.81	0.86	0.90	0.99	1.08
7	0.68	0.74	0.79	0.84	0.89	0.95	1.00	1.05	1.16	1.26
8	0.78	0.84	0.90	0.96	1.02	1.08	1.14	1.20	1.32	1.44
9	0.88	0.95	1.01	1.08	1.15	1.22	1.28	1.35	1.49	1.62
10	0.98	1.05	1.13	1.20	1.28	1.35	1.43	1.50	1.65	1.80
11	1.07	1.16	1.24	1.32	1.40	1.49	1.57	1.65	1.82	1.98
12	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80	1.98	2.16
13	1.27	1.37	1.46	1.56	1.66	1.76	1.85	1.95	2.15	2.34
14	1.37	1.47	1.58	1.68	1.79	1.89	2.00	2.10	2.31	2.52
15	1.46	1.58	1.69	1.80	1.91	2.03	2.14	2.25	2.98	2.70
16	1.56	1.68	1.80	1.92	2.04	2.16	2.28	2.40	2.64	2.88
17	1.66	1.79	1.91	2.04	2.17	2.30	2.42	2.55	2.81	3.06
18	1.76	1.89	2.03	2.16	2.30	2.43	2.57	2.70	2.97	3.24
19	1.85	2.00	2.14	2.28	2.42	2.57	2.71	2.85	3.14	3.42
20	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00	3.30	3.60
21	2.05	2.21	2.36	2.52	2.68	2.84	2.99	3.15	3.47	3.78
22	2.15	2.31	2.48	2.64	2.81	2.97	3.14	3.30	3.63	3.96
23	2.24	2.42	2.59	2.76	2.93	3.11	3.28	3.45	3.80	4.14
24	2.34	2.52	2.70	2.88	3.06	3.24	3.42	3.60	3.96	4.32
25	2.44	2.63	2.81	3.00	3.19	3.38	3.56	3.75	4.13	4.50
26	2.54	2.73	3.93	3.12	3.32	3.51	3.71	3.90	4.29	4.68
27	2.63	2.84	3.04	3.24	3.44	3.65	3.85	4.05	4.46	4.86
28	2.73	2.94	3.13	3.36	3.57	3.78	3.99	4.20	4.62	5.04
29	2.83	3.05	3.26	3.48	3.70	3.92	4.13	4.35	4.79	5.22
30	2.93	3.15	3.38	3.60	3.83	4.05	4.28	4.50	4.95	5.40
31	3.02	2.26	3.49	3.72	3.95	4.19	4.42	4.65	5.12	5.58
32	3.12	2.36	3.60	3.84	4.08	4.32	4.56	4.80	5.28	5.76
33	3.22	2.47	3.71	3.96	4.21	4.46	4.70	4.95	5.45	5.94
34	3.32	2.57	3.83	4.08	4.34	4.59	4.85	5.10	5.61	6.12
35	3.41	2.68	3.94	4.20	4.46	4.73	4.99	5.25	5.78	6.30
36	3.51	2.78	4.05	4.32	4.59	4.86	5.13	5.40	5.94	6.48
37	3.61	2.89	4.16	4.44	4.72	5.00	5.27	5.55	6.11	6.66
38	3.71	2.99	4.28	4.56	4.85	5.13	5.42	5.70	6.27	6.84
39	3.80	4.10	4.39	4.68	4.97	5.37	5.56	5.85	6.44	
40	3.90	4.20	4.50	4.80	5.10	5.40	5.70	6.00	6.60	
41	4.00	4.31	4.61	4.92	2.23	5.54	5.84	6.15	6.77	
42	4.10	4.41	4.73	5.04	5.36	5.67	5.99	6.30		
43	4.19	4.52	4.84	5.16	5.48	5.80	6.13	6.45		
44	4.29	4.62	4.95	5.28	5.61	5.94	6.27	6.60		
45	4.39	4.73	5.06	5.40	5.74	6.08	6.41	6.75		
46	4.49	4.83	5.18	5.52	5.87	6.21	6.56	6.90		
47	4.58	4.94	5.29	5.64	5.99	3.45	6.70			
48	4.68	5.04	5.40	5.76	6.12	6.48	6.84			
49	4.78	5.15	5.51	5.88	6.25	6.62				
50	4.88	5.25	5.63	6.00	6.38	6.75				

Diameter of Wheel	650	700	750	800	850	900	950	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
3	0.59	0.63	0.68	0.72	0.77	0.81	0.86	0.90	0.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80
4	0.78	0.84	0.90	0.96	1.02	1.08	1.14	1.20	1.32	1.44	1.56	1.68	1.80	1.92	2.04	2.16	2.28	2.40
5	0.98	1.05	1.13	1.20	1.28	1.35	1.43	1.50	1.65	1.80	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00
6	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80	1.98	2.16	2.34	2.52	2.70	2.88	3.06	3.24	3.42	3.60
7	1.37	1.47	1.58	1.68	1.79	1.89	2.00	2.10	2.31	2.52	2.73	2.94	3.15	3.36	3.57	3.78	3.99	4.20
8	1.56	1.68	1.80	1.92	2.04	2.16	2.28	2.40	2.64	2.88	3.12	3.36	3.60	3.84	4.08	4.32	4.56	4.80
9	1.76	1.89	2.03	2.16	2.30	2.43	2.57	2.70	2.97	3.24	3.51	3.78	4.05	4.32	4.59	4.86	5.13	5.40
10	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00	3.30	3.60	3.90	4.20	4.50	4.80	5.10	5.40	5.70	6.00
11	2.15	2.31	2.48	2.64	2.81	2.97	3.14	3.30	3.63	3.96	4.29	4.64	4.95	5.28	5.61	5.94	6.27	
12	2.34	2.52	2.70	2.88	3.06	3.24	3.42	3.60	3.96	4.32	4.68	5.04	5.40	5.76	6.12	6.48		
13	2.54	2.73	2.93	3.12	3.32	3.57	3.71	3.90	4.79	4.68	5.07	5.46	5.85	6.24	6.63			
14	2.73	2.94	3.15	3.36	3.57	3.78	3.99	4.20	4.62	5.04	5.46	5.88	6.30	6.72				
15	2.93	3.15	3.38	3.60	3.83	4.05	4.28	4.50	4.95	5.40	5.85	6.30	6.75					
16	3.12	3.36	3.60	3.84	4.08	4.32	4.56	4.80	5.28	5.76	6.24	6.72						
17	3.32	3.57	3.83	4.08	4.34	4.59	4.85	5.10	5.61	6.12	6.63							
18	3.51	3.78	4.05	4.32	4.59	4.86	5.13	5.40	5.94	6.48								
19	3.71	3.99	4.28	4.56	4.85	5.13	5.42	5.70	6.27	6.84								
20	3.90	4.20	4.50	4.80	5.10	5.40	5.70	6.00	6.60									
21	4.10	4.41	4.73	5.04	5.36	5.67	5.99	6.30	6.93									
22	4.29	4.62	4.95	5.28	5.61	5.94	6.27	6.60										
23	4.49	4.83	5.18	5.52	5.87	6.21	6.56											
24	4.68	5.04	5.40	5.76	6.12	6.48	6.84											
25	4.88	5.25	5.63	6.00	6.38	6.75												
26	5.07	5.46	5.85	6.24	6.53													
27	5.27	5.67	6.08	6.48	6.89													
28	5.46	5.88	6.30	6.72														
29	5.66	6.09	6.53															
30	5.85	6.30	6.75															
31	6.05	6.51																
32	6.24	6.72																
33	6.44																	
34	6.63																	
35	6.83																	

The formula used in calculating this table is

h. p. = 0.0003 dWN

Where d = diameter of wheel

W = width of face

N = revolutions per minute.

To determine the power which may be transmitted by friction wheels of sulphite fiber, leather fiber, leather, and tarred fiber the values of this table should be multiplied by the following constants:

Sulphite fiber,	1.23
Leather fiber,	1.97
Leather,	0.53
Tarred fiber,	0.97

multiplied by 1.2. Such of these multipliers as are likely to be most used are presented with the table.

49 A more flexible means of approach to the general problem involved by the use of fibrous friction wheels than that which is supplied by Table 10 is supplied by Fig. 36. This chart gives a convenient means of determining the value of any one of the variable factors in the formula h. p. = 0.0003 dWN for the straw fiber friction wheel working in combination with an iron follower, the remaining factors being known or assumed. To transform values thus found to corresponding ones for the other possible combinations of wheels, it is only necessary to multiply by the proper factor chosen from the table of multipliers given in the preceding paragraph. The use of the chart may be illustrated as follows:

a *To find surface speed,* locate the intersection of the vertical line representing the given speed in revolutions per minute with the diagonal one representing the given diameter. The horizontal line passing through this point will give the surface speed in feet per minute on the vertical scale to the right of the diagram.

b *To find the horse power for a given wheel,* locate the intersection of the vertical line representing the given speed in revolutions per minute with the diagonal line representing the given diameter. Follow the horizontal line passing through this point to the right or left until the intersection between it and the vertical line representing the given width, as shown on the scale at the top of the diagram, is reached The diagonal line passing through this point marked "Total horse power" will represent the required horse power.

c *To find the face width of a given wheel* necessary to transmit a given horse power, the speed being known, locate the intersection of the vertical line representing the given speed in revolutions per minute with the diagonal line representing the given diameter. Follow the horizontal line passing through this point to the right or left until the intersection between it and the diagonal line representing the required horse power is reached. The vertical line passing through this point will give the width of face in inches on the scale at the top of the diagram.

Application of Results to Forms Other than Those Experimented Upon

FACE FRICTION GEARING

50 A fibrous driving wheel, acting upon the face of a metal disc, constitutes a form of friction gear which is serviceable for a variety of purposes. If the driver is so mounted that it may be moved across the face of the disc, the velocity ratio may be varied, and the direction of the disc's motion may be reversed. The contact is not one of pure rolling. If the driver is cylindrical in form, the action along its line of contact with the disc is attended by slip, the amount of which changes for every different point along the line. The recognition of this fact is essential to a discussion of the power transmitting capacity of the device.

51 Experiments involving the spur form of friction wheels already described have shown that slip greatly affects the coefficient of friction; that the coefficient approaches its maximum value when the slip reaches 2 per cent, and that when the slip exceeds 3 per cent, the coefficient diminishes. It is known that reductions in the value of the coefficient with increments of slip beyond 3 per cent are at first gradual, although the characteristics of the testing machine have not permitted a definition of this relation for slip greater than 4 per cent. The experiments, however, fully justify the statement that for maximum results, the slippage should not be less than 2 per cent nor more than 4 per cent. It is the maximum limit with which we are concerned in considering the amount of power which may be transmitted by face friction gearing.

52 From the discussion of the previous paragraph, it should be evident that, for best results, the width of face of the friction driver, and the distance between the driver and center of disc, should always be such that the variations in the velocity of the particles of the disc having contact with the driver will not exceed 4 per cent. A convenient rule which, if followed, will secure this condition, is to make the minimum distance between the driver and the center of the driven disc twelve times the width of the face of the driver. For example, a driver having a ¼ inch width of face should be run at a distance of 3 inches or more from the center of the disc. Similarly, drivers having faces ½, 1 or 2 inches in width should be run at a distance from the center of the disc of not less than 6, 12 or 24 inches, respectively. When these conditions are met, all formulæ for calculating the power which may be transmitted, also, the values of Table 10, apply directly to the conditions of face driving.

53 It may not infrequently happen that friction wheels must be run nearer the center of the disc than the distance specified, and there is, of course, no objection to such practice, but it should not be forgotten that as the center of the disc is approached, the coefficient of friction, and consequently, the capacity to transmit power, diminishes.

CONDITIONS TO BE OBSERVED IN THE INSTALLATION OF FRICTION DRIVES

54 Whatever may be the form of the transmission, the fibrous wheel must always be the driver. Neglect of this rule is likely to result in failure which will appear in the unequal wear of the softer wheel, occasioned by slippage.

55 The rolling surfaces of the wheel should be kept clean. Ordinarily, they should not be permitted to collect grease or oil, nor be exposed to excessive moisture. Where this can not be prevented, a factor of safety should be provided by making the wheels larger than normal for the power to be transmitted.

56 Since the power transmitted is directly proportional to the pressure of contact, it is a matter of prime importance that the mechanical means employed in maintaining the contact be as nearly as possible inflexible. For example, arrangements of friction wheels which involve the maintenance of contact through the direct action of a spring have been found unsatisfactory, since any defect in the form of either wheel introduces vibrations which tend to impair the value of the arrangement. It is recommended that springs be avoided and that contact be secured through mechanism which is rigid and which when once adjusted shall be incapable of bringing about any release of the pressure to which it is set.

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APPENDIX

A SUMMARY OF OBSERVED AND CALCULATED RESULTS

TABLE 1 SUMMARY OF DATA STRAW FIBER

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
1	Iron	182	0.56	150	0.153
2	Iron	173	0.58	150	0.179
3	Iron	174	0.61	150	0.213
4	Iron	207	0.78	150	0.271
5	Iron	207	0.99	150	0.313
6	Iron	200	1.10	150	0.359
7	Iron	175	1.40	150	0.386
8	Iron	200	1.22	150	0.381
9	Iron	173	1.94	150	0.411
10	Iron	203	2.25	150	0.458
11	Iron	203	2.79	150	0.473
12	Iron	205	2.33	150	0.463
13	Iron	206	3.15	150	0.465
14	Iron	173	1.04	150	0.368
15	Iron	178	1.75	150	0.405
16	Iron	170	2.00	150	0.432
17	Iron	170	3.90	150	0.446
18	Iron	220	2.02	100	0.430
19	Iron	220	2.00	125	0.431
20	Iron	220	2.10	175	0.432
21	Iron	200	1.80	200	0.436
22	Iron	157	1.62	225	0.440
23	Iron	180	2.20	150	0.420
24	Iron	174	2.10	200	0.427
25	Iron	161	2.25	250	0.422
26	Iron	165	2.02	300	0.405
27	Iron	165	2.02	350	0.401
28	Iron	211	2.12	400	0.410
29	Iron	210	0.65	400	0.129
30	Iron	222	0.87	400	0.217
31	Iron	219	0.88	400	0.228
32	Iron	216	0.90	400	0.234
33	Iron	216	0.93	400	0.275
34	Iron	210	1.16	400	0.318
35	Iron	162	1.80	400	0.400
36	Iron	212	3.00	400	0.435
37	Aluminum	190	0.53	150	0.162
38	Aluminum	195	0.57	150	0.212
39	Aluminum	210	0.60	150	0.215
40	Aluminum	190	0.63	150	0.244
41	Aluminum	195	0.78	150	0.290
42	Aluminum	215	1.26	150	0.372
43	Aluminum	212	1.56	150	0.395
44	Aluminum	200	1.79	150	0.421
45	Aluminum	196	1.90	150	0.446
46	Aluminum	197	3.01	150	0.481
47	Aluminum	193	3.26	150	0.499
48	Aluminum	213	2.12	100	0.464
49	Aluminum	212	1.90	100	0.458
50	Aluminum	213	1.86	125	0.453

TABLE 1 SUMMARY OF DATA STRAW FIBER—Continued

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
51	Aluminum	212	2.27	125	0.462
52	Aluminum	212	1.80	175	0.451
53	Aluminum	202	1.86	175	0.471
54	Aluminum	203	2.02	200	0.468
55	Aluminum	214	2.10	200	0.453
56	Aluminum	202	1.80	225	0.445
57	Aluminum	210	2.20	250	0.458
58	Aluminum	210	2.05	300	0.445
59	Aluminum	210	2.15	350	0.437
60	Aluminum	210	1.93	400	0.440
61	Type Metal	214	0.50	150	0.114
62	Type Metal	180	0.58	150	0.164
63	Type Metal	209	0.63	150	0.153
64	Type Metal	223	0.71	150	0.191
65	Type Metal	194	0.73	150	0.199
66	Type Metal	226	0.84	150	0.229
67	Type Metal	187	1.12	150	0.233
68	Type Metal	220	1.18	150	0.244
69	Type Metal	220	1.20	150	0.262
70	Type Metal	188	1.50	150	0.246
71	Type Metal	190	1.54	150	0.252
72	Type Metal	220	1.70	150	0.276
73	Type Metal	187	1.73	150	0.256
74	Type Metal	180	2.01	150	0.290
75	Type Metal	211	2.07	150	0.302
76	Type Metal	180	2.40	150	0.298
77	Type Metal	211	3.48	150	0.317
78	Type Metal	218	3.84	150	0.308
79	Type Metal	209	4.80	150	0.332
80	Type Metal	173	1.70	100	0.327
81	Type Metal	180	1.84	125	0.317
82	Type Metal	208	2.00	150	0.306
83	Type Metal	214	1.90	175	0.295
84	Type Metal	211	2.30	200	0.295
85	Type Metal	209	2.01	225	0.294
86	Type Metal	208	2.10	250	0.288
87	Type Metal	210	2.10	300	0.290

TABLE 2 SUMMARY OF DATA STRAW FIBER BELT DRESSING

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
88	Iron	225	0.80	150	0.053
89	Iron	225	0.88	150	0.061
90	Iron	220	1.33	150	0.084
91	Iron	225	1.35	150	0.092
92	Iron	223	1.60	150	0.107
93	Iron	224	2.00	150	0.119
94	Iron	223	2.15	150	0.133
95	Iron	220	2.16	150	0.111
96	Iron	220	3.31	150	0.130
97	Iron	182	2.18	200	0.122
98	Iron	182	2.30	250	0.124
99	Iron	180	2.12	300	0.111
100	Iron	180	2.18	350	0.109
101	Iron	186	2.20	400	0.103
102	Iron	215	2.20	450	0.100
103	Iron	220	2.20	500	0.100

TABLE 3 SUMMARY OF DATA LEATHER FIBER

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
104	Iron..............	179	0.64	150	0.146
105	Iron..............	175	0.70	150	0.213
106	Iron..............	167	0.75	150	0.262
107	Iron..............	178	0.86	150	0.297
108	Iron..............	180	0.94	150	0.396
109	Iron..............	170	1.30	150	0.411
110	Iron..............	210	1.54	150	0.460
111	Iron..............	208	1.58	150	0.484
112	Iron..............	208	1.74	150	0.505
113	Iron..............	208	1.90	150	0.519
114	Iron..............	190	2.32	150	0.534
115	Iron..............	168	2.45	150	0.512
116	Iron..............	168	2.80	150	0.542
117	Iron..............	191	2.90	150	0.565
118	Iron..............	206	1.98	200	0.526
119	Iron..............	200	2.04	250	0.509
120	Iron..............	200	2.00	300	0.510
121	Iron..............	200	2.05	350	0.498
122	Iron..............	220	0.64	300	0.122
123	Iron..............	200	0.94	300	0.300
124	Iron..............	198	1.05	300	0.374
125	Iron..............	190	1.22	300	0.443
126	Iron..............	211	1.60	300	0.474
127	Iron..............	190	2.85	300	0.530
128	Aluminum..........	211	1.92	400	0.481
129	Aluminum..........	211	2.01	350	0.480
130	Aluminum..........	211	2.10	300	0.485
131	Aluminum..........	211	2.15	250	0.502
132	Aluminum..........	211	2.00	200	0.490
133	Aluminum..........	211	2.00	150	0.490
134	Type Metal........	220	0.75	150	0.163
135	Type Metal........	220	0.97	150	0.222
136	Type Metal........	220	1.05	150	0.222
137	Type Metal........	220	1.30	150	0.254
138	Type Metal........	220	1.78	150	0.298
139	Type Metal........	220	2.20	150	0.320
140	Type Metal........	220	2.75	150	0.336
141	Type Metal........	220	3.80	150	0.336
142	Type Metal........	216	2.05	200	0.304
143	Type Metal........	216	2.08	250	0.311
144	Type Metal........	217	2.10	300	0.313
145	Type Metal........	207	1.90	350	0.314
146	Type Metal........	207	2.00	400	0.310

TABLE 4 SUMMARY OF DATA TARRED FIBER

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
147	Iron	220	0.30	150	0.115
148	Iron	220	0.40	150	0.160
149	Iron	220	0.50	150	0.125
150	Iron	220	0.80	150	0.190
151	Iron	220	1.15	150	0.225
152	Iron	219	1.52	150	0.235
153	Iron	218	2.05	150	0.256
154	Iron	220	4.30	150	0.275
155	Iron	220	1.85	200	0.232
156	Iron	220	1.25	250	0.217
157	Iron	220	1.40	300	0.215
158	Iron	220	1.65	350	0.216
159	Iron	220	1.36	400	0.210
160	Iron	220	0.40	400	0.115
161	Iron	220	0.45	400	0.134
162	Iron	216	0.46	400	0.151
163	Iron	219	0.56	400	0.166
164	Iron	220	1.00	400	0.191
165	Iron	220	1.74	400	0.212
166	Iron	222	2.56	400	0.223
167	Aluminum	220	0.30	400	0.062
168	Aluminum	220	0.42	400	0.145
169	Aluminum	221	0.55	400	0.171
170	Aluminum	220	0.55	400	0.212
171	Aluminum	220	0.60	400	0.225
172	Aluminum	216	0.60	400	0.200
173	Aluminum	220	0.72	400	0.235
174	Aluminum	220	0.82	400	0.245
175	Aluminum	220	1.10	400	0.263
176	Aluminum	216	1.20	400	0.270
177	Aluminum	215	1.40	400	0.266
178	Aluminum	216	1.83	400	0.286
179	Aluminum	219	2.50	400	0.300
180	Aluminum	219	3.10	400	0.310
181	Aluminum	220	2.12	150	0.317
182	Aluminum	220	1.70	200	[illegible]
183	Aluminum	180	2.10	250	0.303
184	Aluminum	180	2.00	300	0.300
185	Aluminum	191	1.90	350	0.295
186	Aluminum	190	2.05	400	0.290
187	Type Metal	230	0.54	400	0.057
188	Type Metal	229	0.63	400	0.083
189	Type Metal	227	0.70	400	0.103
190	Type Metal	227	0.73	400	0.117
191	Type Metal	227	0.80	400	0.140
192	Type Metal	220	1.00	400	0.211
193	Type Metal	220	1.10	400	0.221
194	Type Metal	220	1.26	400	0.220
195	Type Metal	220	1.60	400	0.255
196	Type Metal	220	2.00	400	0.270
197	Type Metal	220	2.75	400	0.285
198	Type Metal	224	2.00	350	0.270
199	Type Metal	225	2.00	300	0.275
200	Type Metal	227	2.00	250	0.270
201	Type Metal	226	2.00	200	0.269
202	Type Metal	227	2.00	150	0.280
267	Iron	210	1.90	200	0.174
268	Iron	211	1.96	300	0.168
269	Iron	210	2.16	400	0.164

TABLE 5 SUMMARY OF DATA LEATHER

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
203	Iron	215	0.65	400	0.113
204	Iron	212	0.68	400	0.086
205	Iron	212	0.86	400	0.109
206	Iron	212	0.94	400	0.120
207	Iron	211	0.95	400	0.137
208	Iron	211	1.04	400	0.153
209	Iron	212	1.10	400	0.160
210	Iron	213	1.13	400	0.137
211	Iron	213	1.35	400	0.183
212	Iron	211	1.35	400	0.176
213	Iron	216	1.56	400	0.163
214	Iron	215	1.60	400	0.183
215	Iron	208	2.00	400	0.200
216	Iron	212	2.40	350	0.245
217	Iron	210	2.30	300	0.244
218	Iron	212	2.20	250	0.237
219	Iron	209	1.92	200	0.225
220	Iron	213	2.00	150	0.213
221	Aluminum	211	0.64	300	0.115
222	Aluminum	209	0.80	300	0.160
223	Aluminum	210	1.12	300	0.201
224	Aluminum	213	1.40	300	0.233
225	Aluminum	214	1.70	300	0.260
226	Aluminum	210	1.50	300	0.267
227	Aluminum	210	1.85	300	0.279
228	Aluminum	209	2.45	300	0.310
229	Aluminum	210	3.00	300	0.313
230	Aluminum	211	2.30	350	0.320
231	Aluminum	211	2.00	300	0.305
232	Aluminum	213	1.90	250	0.316
233	Aluminum	214	1.92	200	0.348
234	Aluminum	215	1.92	150	0.380
235	Type Metal	212	1.90	150	0.412
236	Type Metal	213	2.00	200	0.400
237	Type Metal	211	2.10	250	0.389
238	Type Metal	214	2.35	300	0.361
239	Type Metal	214	2.00	350	0.350

TABLE 6 SUMMARY OF DATA SULPHITE FIBER

No.	Follower	Revolutions per minute	Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
A	B	C	D	E	F
240	Iron	211	1.75	150	0.546
241	Iron	211	2.15	200	0.549
242	Iron	210	1.70	250	0.550
243	Iron	211	1.90	300	0.512
244	Iron	210	1.70	350	0.505
245	Aluminum	211	2.00	150	0.535
246	Aluminum	211	2.20	200	0.527
247	Aluminum	211	2.26	250	0.522
248	Aluminum	211	2.10	300	0.520
249	Aluminum	211	2.10	350	0.523
250	Type metal	211	1.80	150	0.505
251	Type metal	211	1.95	200	0.516
252	Type metal	210	1.90	250	0.513
253	Type metal	211	1.75	300	0.490
254	Type metal	212	1.75	350	0.510

TABLE 7 SUMMARY OF DATA STRAW FIBER—IRON

No.	Speed		Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
	Revolutions per minute	Feet per minute			
A	B	C	D	E	F
255	107	450	2.15	200	0.446
256	107	450	2.06	300	0.443
257	107	450	2.02	400	0.412
21	200	836	1.80	200	0.436
26	165	690	2.02	300	0.405
28	211	882	2.12	400	0.410
258	800	3350	2.09	150	0.472
259	800	3350	2.05	200	0.480
260	800	3350	1.91	250	0.440

TABLE 8 SUMMARY OF DATA TARRED FIBER—IRON

No.	Speed		Slip (per cent)	Contact pressure (pounds per inch)	Coefficient of friction
	Revolutions per minute	Feet per minute			
A	B	C	D	E	F
261	107	450	1.88	150	0.290
262	107	450	2.06	250	0.289
263	107	450	1.90	400	0.287
153	218	910	2.05	150	0.256
156	220	920	2.00	250	0.240
166	220	920	2.56	400	0.223
264	800	3350	2.04	150	0.306
265	800	3350	2.10	250	0.287
266	800	3350	1.85	400	0.301

TABLE 9 COEFFICIENT OF FRICTION

	Coefficient of Friction when Contact Pressure is 150 Pounds Per Inch		
	Iron	Aluminum	Type Metal
Sulphite Fiber	0.550	0.530	0.515
Leather Fiber	0.515	0.495	0.305
Straw Fiber	0.425	0.455	0.310
Tarred Fiber	0.250	0.305	0.275
Leather	0.225	0.360	0.410
Straw fiber with belt dressing	0.120	—	—